

C & D BATTERIES
DIV OF
THE ELECTRIC AUTOLITE CO.

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TITLE:

9/16
SATTELITE BATTERY
Preliminary Evaluation of Design
Possibilities

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OBJECT: To determine whether the lead-calcium battery has the
characteristics which justify development of a satellite battery.

ABSTRACT: 6.9 watt hours per pound of cell has been obtained for 250 cycles using a 30 minute discharge and a 90 minute charge period at 77° F. At the end of this period the cells appeared in perfect condition. It appears possible to obtain 10 watt hours per pound by using thinner plates, but at some sacrifice of life.

Matters still requiring study are life tests, sealing methods, and gas disposal. Work in this area is continuing.

These cells have promise because of the higher voltage per cell, the smaller number required, an absence of magnetic field, an 80% voltage efficiency, or more, and a 98% current efficiency. Furthermore, the operation of large size cells without too much internal heat appears feasible.

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SUMMARY

This report marks the completion of phase 1 of the subject contract. It establishes the probable limitations in power output of lead-acid batteries when used in a test cycle featuring 30 minutes discharge and 60 minutes charge.

6.9 watt hours per pound was obtained using a test cell containing 0.090 inch thick plates. The test was continued for 250 cycles at 77° F without deterioration of capacity or apparent change in the cell.

6.2 watt hours per pound was obtained at 32° F on a similar cell during a series of capacity test discharges, but it was found that charge could not be completed in 60 minutes, so that the power actually available on a 90 minute cycle would be somewhat less. The actual available capacity has not yet been determined.

Data is available to indicate that the use of 0.040 inch plates will deliver 10 watt hours per pound at 77°. The effect of plate thickness on the charge process at 32° indicates that an output of 5 watt hours per pound or more will be obtained.

Preliminary tests indicate that gas evolution on open circuit is unmeasurable and amounts to less than 30×10^{-6} cc/Hr/AH capacity.

Remaining to be studied in phase 2 of the project are the following:

1. Usable capacity during cycle tests at 32° F.
2. Gas evolution during charge and discharge.
3. Life tests.
4. Methods of absorbing gas which may be formed.
5. Reliability of sealing methods.
6. Design and pilot models of thin plate batteries.
7. Test of pilot model cells.

EXPERIMENTAL

Power output: Table 1 shows the power output for cells which have been fully charged. The first column shows the experimental results using cells which were available for test, while the second column shows the calculated results assuming that cells of optimum design were available.

Preliminary tests were also run on cells containing positive plates 0.266 inches thick. These are designed for long life at a low discharge rate and gave the expected low capacity at the 30 minute discharge rate. The cells shown in table 2 had plates 0.090 inches thick and gave a reasonably good performance. The optimum design is based on plates 0.040 inches thick. Since the test data from the first two constructions fit our design curves, we feel confident that the same design curves can be used to predict the output of the 0.040 inch plates.

The first tests on 0.090 inch thick positive which were defective. The plates had received other tests previously and had been allowed to stand idle for a long time. They did not give the expected capacity and a new set of batteries was prepared. The data in the table are for this new set of batteries.

Table 1 Power Output
Fully Charged Cells

	<u>Experimental</u>	<u>Calculated</u>
Plate Thickness	0.090	0.040
Nominal Capacity 8 Hr. rate @ 77°	17 WH/lb.	15 WH/lb.
Test capacity 30 min. rate @ 77°	6.9 WH/lb.	10.5 WH/lb.
Test capacity 30 min. rate @ 32°	6.2 WH/lb.	9.4 WH/lb.

Charge Time:

The charge-discharge characteristics during the cycle test are shown in Fig. 1-4, where the charge time was prolonged to 2 hours to show details of the charge characteristics.

Fig. 1 shows the current and voltage during cycle at 77° F. Here charge appears substantially complete in 60 minutes at 77° F. This was checked by putting the test cell on automatic life cycle for 2 weeks using the 60 minute charge and 30 minute discharge. There was no deterioration of capacity and we, therefore, feel that charge is substantially complete in 60 minutes.

Figure 2 shows similar data during a test at 32° F. Here it is obvious that charge is not complete in 60 minutes and that the capacity available during a cycle life test will be controlled by the amount of charge the battery will accept. This has not yet been verified by a life cycle test and such a test is clearly necessary in order to learn the power output available. This is particularly important since we do not yet know how this charge acceptance varies with battery life and the maximum capacity at which battery operation will stabilize.

Fig. 3 shows the charge characteristics in a different fashion. The standard rule for charging a battery is that it will accept at least 1 ampere of current for every ampere hour equivalent to the lead sulfate in the battery plate. The dotted line on the chart shows the limitation of this rule, while the experimental data shows this rule still applies. It shows clearly that data can be plotted on what is almost a straight line and that at 60 minutes, charge is substantially 100% at 77°, while at 32° it is only 86% complete.

Attempts to shorten the charge period by using a higher voltage were made and are shown in Fig. 4, 5 and 6. Here it is clear that after 60 minutes of charge the battery is still accepting 0.4 to 0.6 amperes at each voltage and obviously the battery is not fully charged because the charge current keeps decreasing.

Optimum Design:

For satellite application, we have mentioned that a 0.040 thick plate appears to be about optimum. Thick plates give their maximum output only when the discharge time is long. Extremely thin plates are difficult to make and have a relatively short life. We feel that 0.040 inch plates strike about the best practical performance within the life requirements. The effect of plate thickness is shown best in Fig. 7 prepared from data by Harner and Chub (Reference 1). We have extended this work into the range of thinner plates (Reference 2) and have obtained analogous data on negative plate and electrolyte volume. (Proprietary information).

It is on this basis that we feel safe in estimating that 10 watt hours per pound can be obtained during a 30 minute discharge.

Low Temperature Capacity:

Capacity data at 32° is available in reference #2 and Fig. 8 and is the basis for our estimate of battery output where the capacity is limited by the amount of active material, not by charge acceptance.

Low Temperature Charge:

The effect of temperature on the charge acceptance has been investigated (Reference 3). The data from this reference are plotted in Fig. 9 showing how it compares with data obtained in this work. In view of the difference in test cells and test methods, there is no doubt that the present work come close enough to the earlier work to justify extrapolating the line to lower temperatures and concluding that at temperatures of less than 32° the charge time will fall into a range which makes the battery take a long time for a complete charge. Whether this is a fatal objection depends on getting more data.

Gas Evolution Tests:

Because of the small amount of gas anticipated, we have run tests using a set of 500 ampere hour batteries and measured the pressure rise with a oil manometer. After two weeks there was no detectable gas evolved and only the normal day-to-day variations in pressure due to changes of temperature and barometric pressure.

One cell was flushed with hydrogen to give a 70 mm added pressure. This cell maintained its added pressure and shows that we were not measuring a leaky cell or hydrogen diffusion, but that the actual gas evolution was actually close to zero.

On the basis of this test we feel that hydrogen evolution amounts to not more than 30×10^{-6} cc per hour per ampere hour of rated capacity when the cell is on open circuit.

Future Work:

In view of the results obtained we believe that additional work on the lead-acid system is justified and propose that the following program be started:

1. Prepare batteries of the present design with 0.090 plates and put them on life test at 77°.
2. Prepare a duplicate set of batteries and set up life test at 32°F. to determine the actual available capacity on a 90 minute test cycle and then determine the life on such a cycle.
3. Measure gas evolution rate during charge and discharge to supplement the open circuit test already available.
4. If the gas evolution is sufficient to require means of absorbing it, study those methods which appear practical.
5. Design and test sealing procedures.
6. If everything is favorable, design and construct cells to meet the performance requirements.

FIG. 1
Missile Battery
Typical Cycle @ 77°F
2.3 Volt Charge

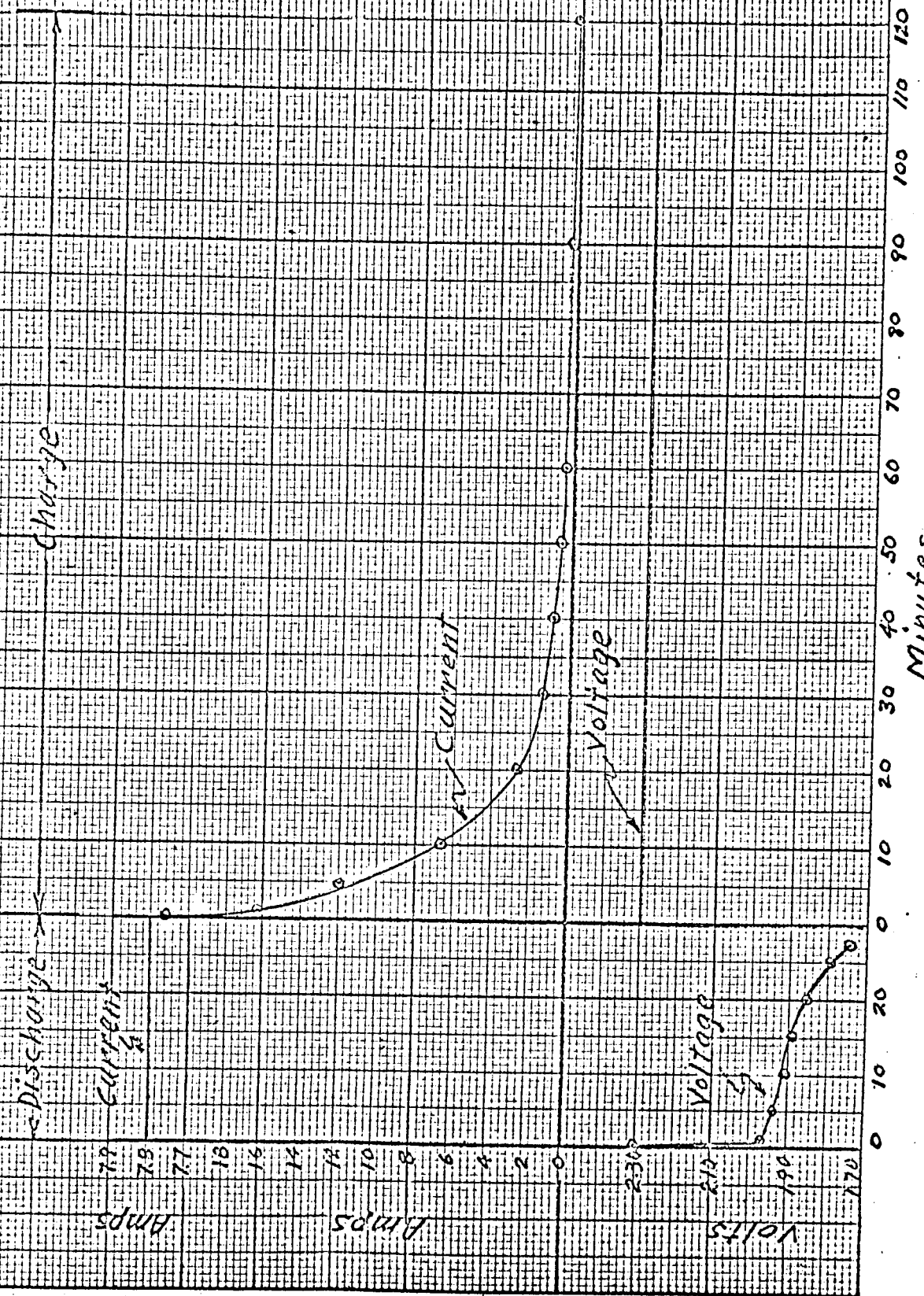


FIG. 2
Missile Battery
Typical Cycle @ 32°F
2.3 Volt Charge

Charge

Discharge
current

Current

Voltage

Voltage

Minutes

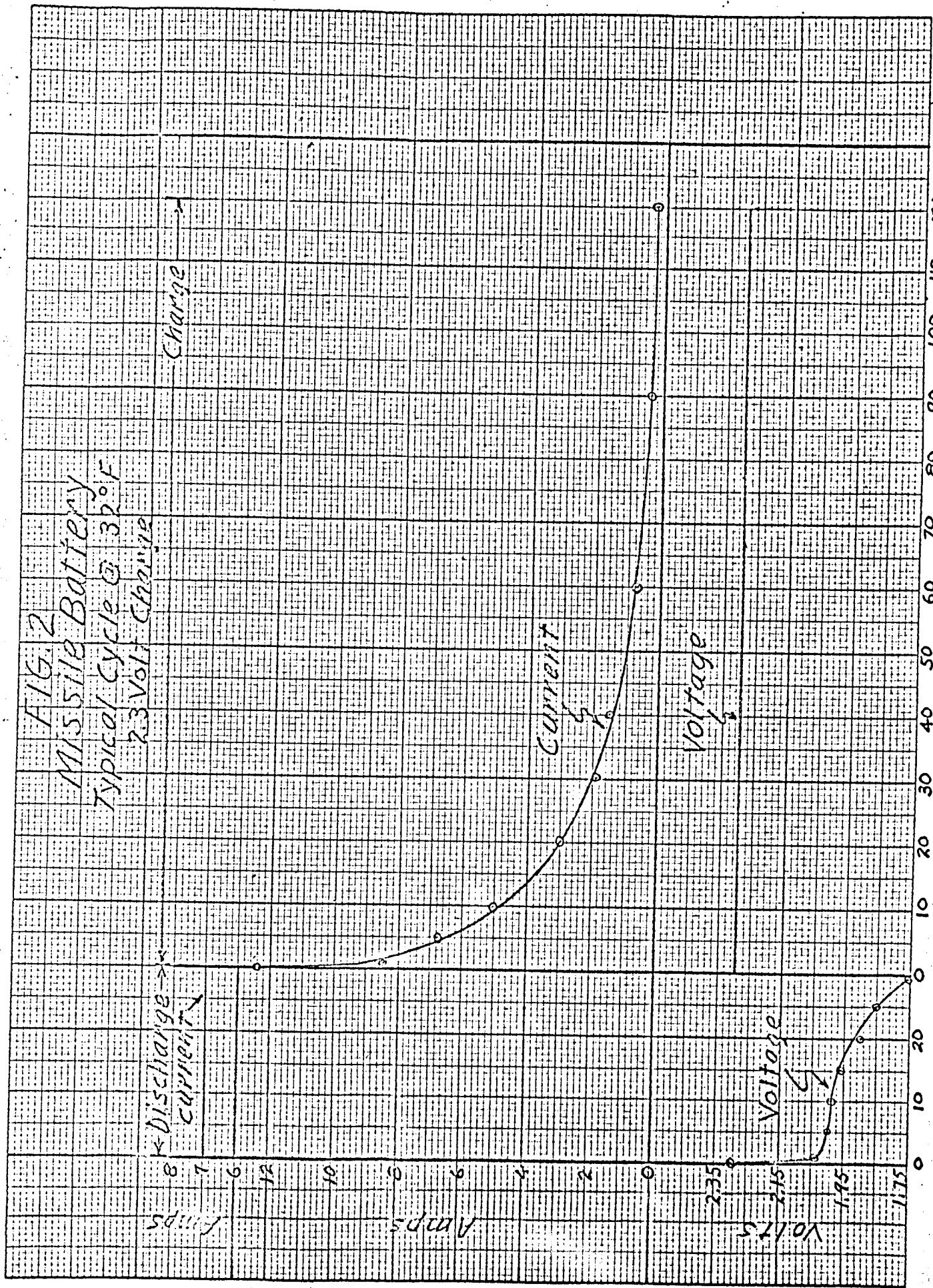
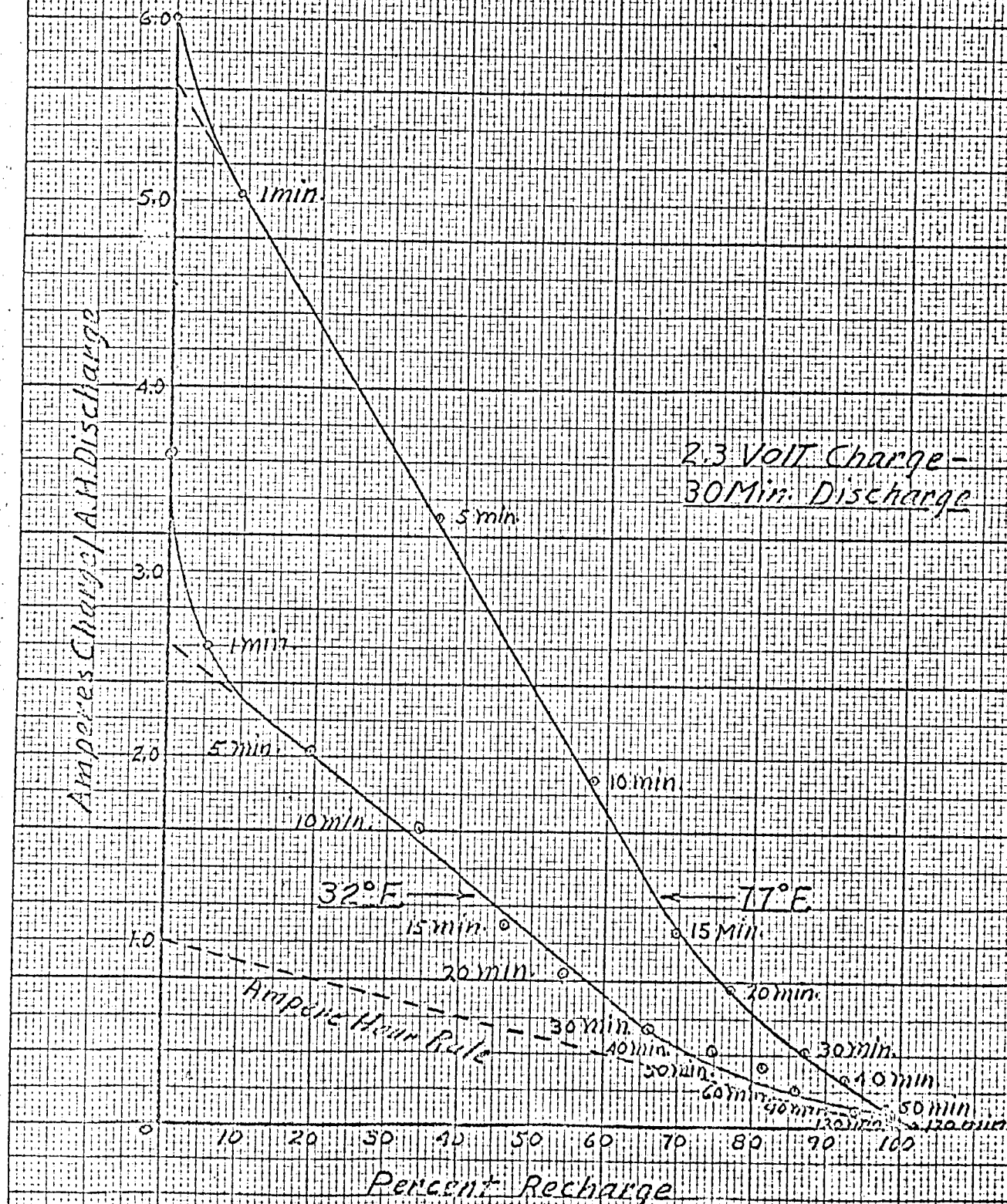


FIG. 3

CHARGE-RECHARGE TEST



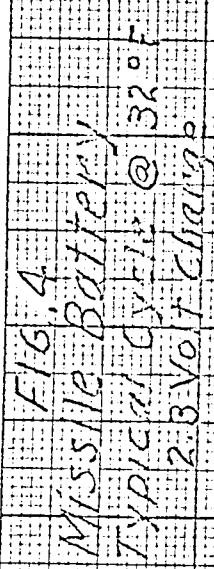


FIG. 5
Missile Battery
Typical Cycle @ 32°F
2.4 Volt Charge

Charge

Discharge

Current
Amps

Current
Amps

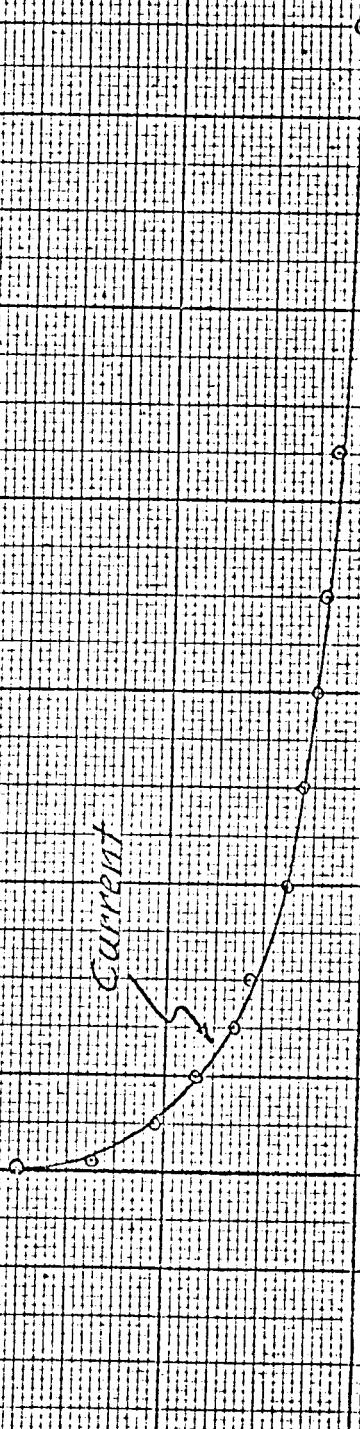
Voltage
Volts

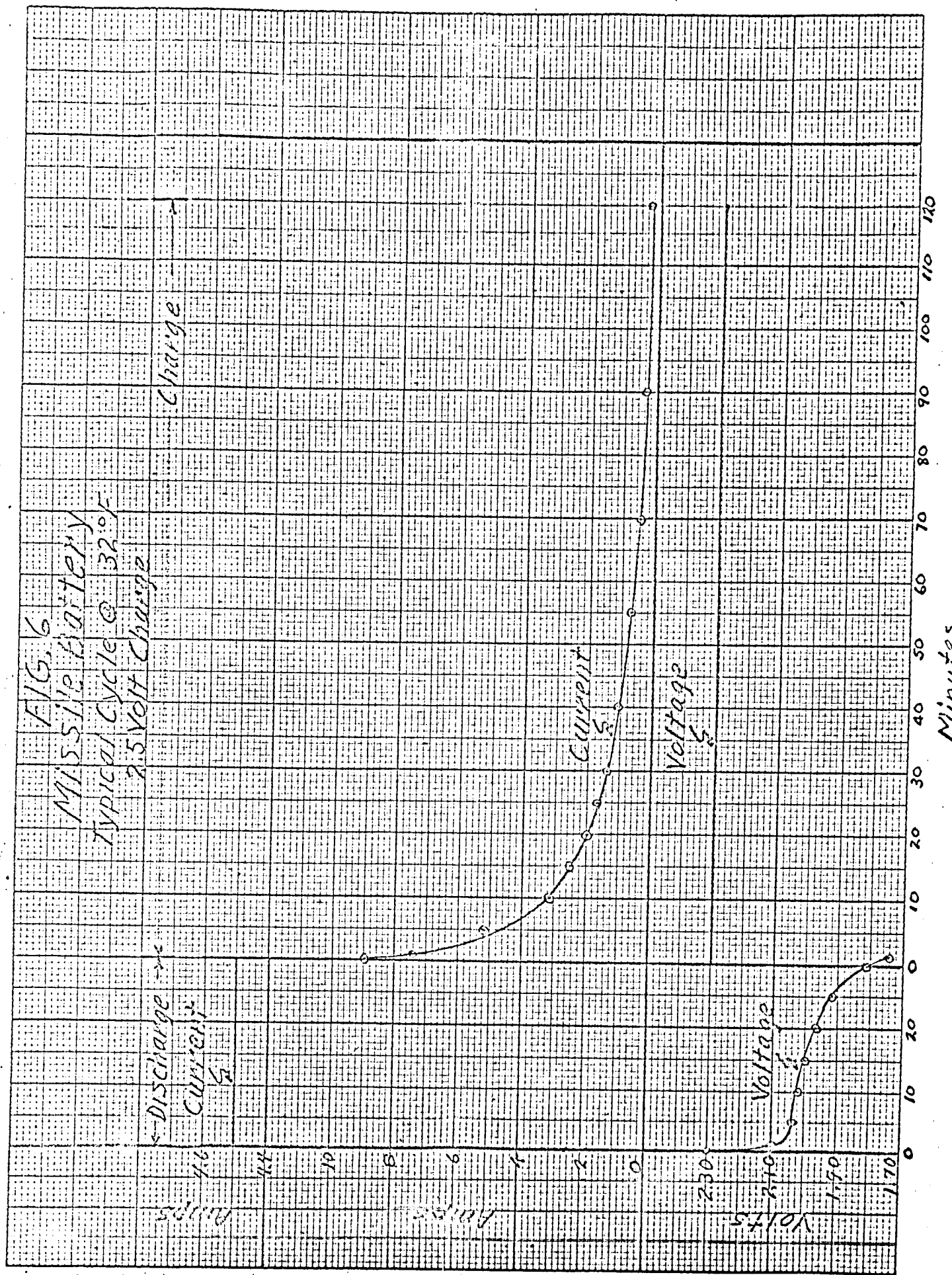
Voltage
Volts

6.0
4.5
3.0
1.5
0

6
4
2
0

2.30
2.10
1.90
1.70





1.57
10.57

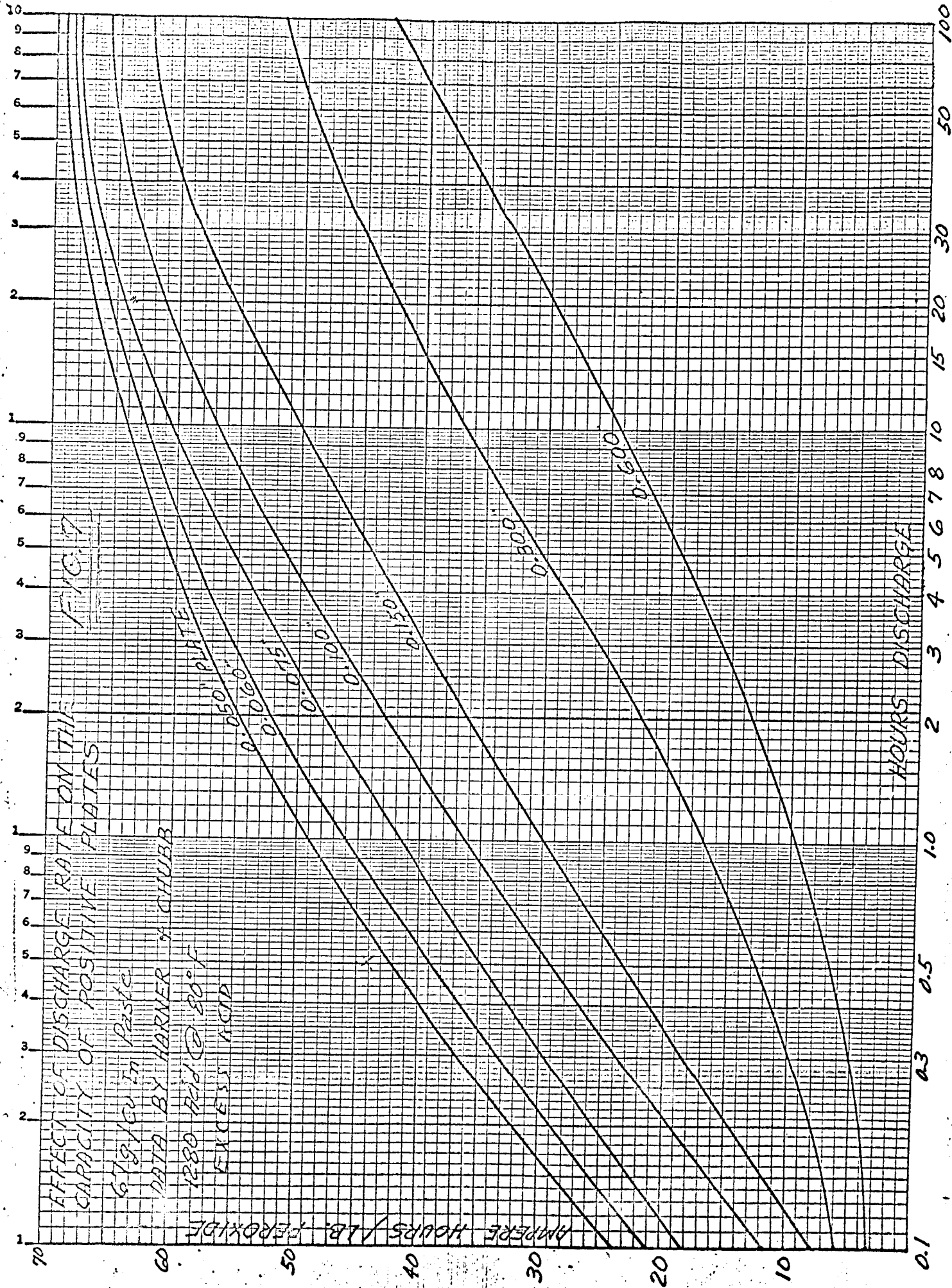


Fig 8

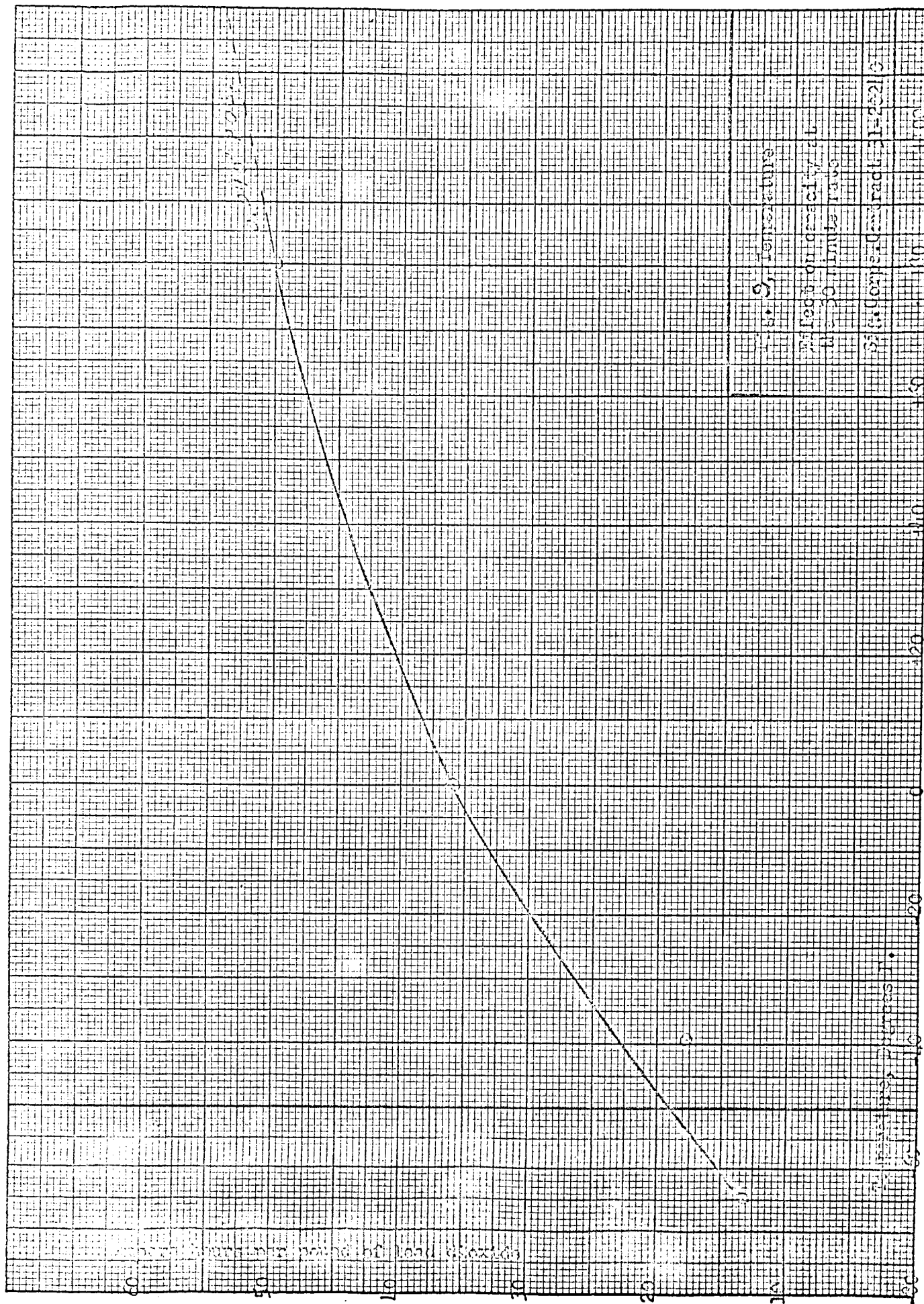
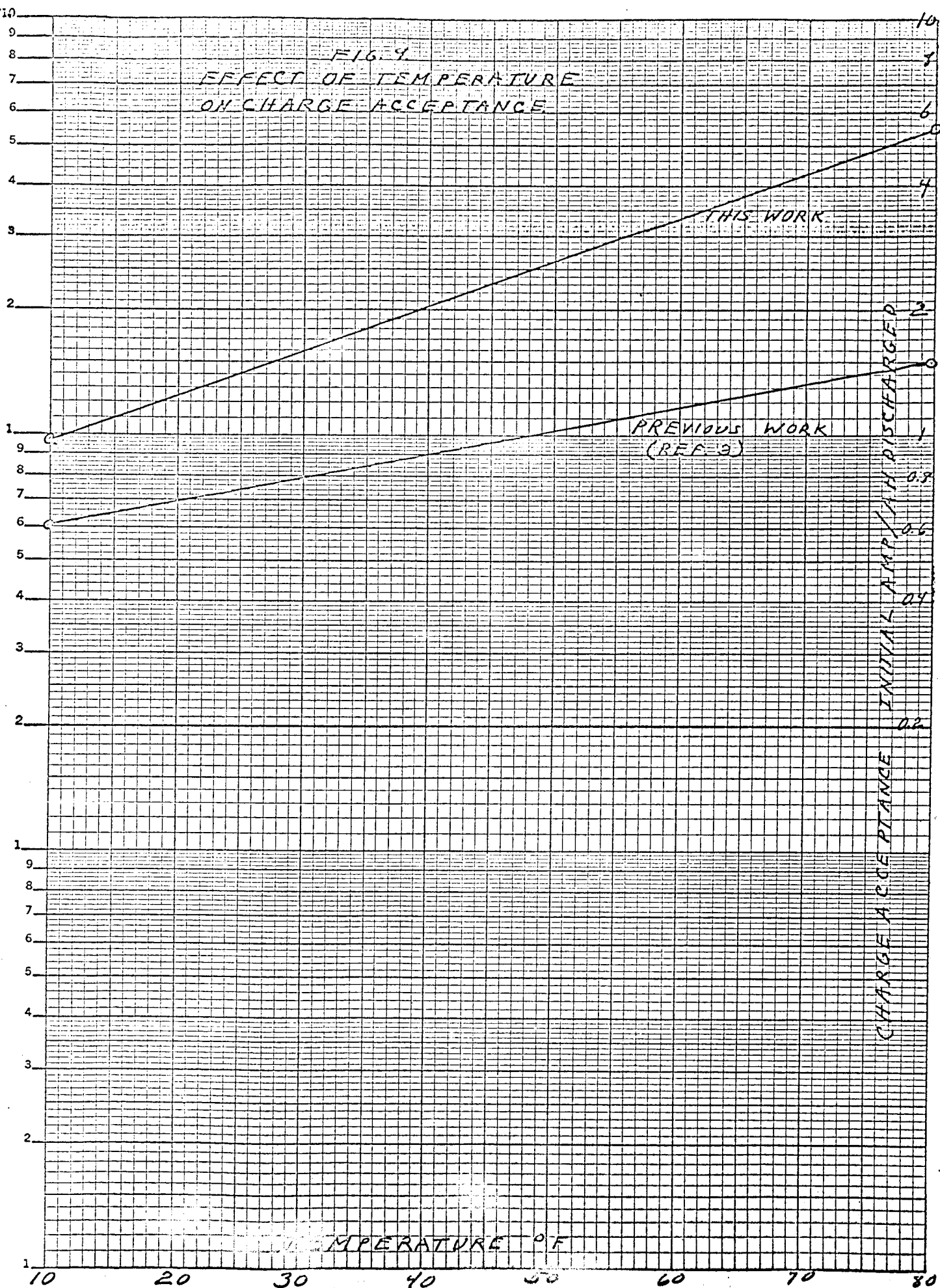


FIG. 1
 EFFECT OF TEMPERATURE
 ON CHARGE ACCEPTANCE



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Final Report - October 1, 1952
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Contract W36-039-sc-38233
Department of Army - Project No. 3-91-02804
Signal Corps - Project No. 31 2023A-2 (C-540-1)